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(54) Title of the Invention: A High Strength Copper Alloy with High Electrical Conductivity and Superior Oxide Film Adhesiveness

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## Specification

### 1. Title of the Invention

A High Strength Copper Alloy with High Electrical Conductivity and Superior Oxide Film Adhesiveness

### 2. Claims

(1) A high-strength copper alloy with high electrical conductivity and superior oxide film adhesiveness characterized in that it contains from 0.1 weight % to 10 weight % Mn, in that it contains a total quantity of from 0.01 weight % to 10 weight % of one or two or more elements selected from the group comprised of the following: B, P, Be, Al, As, Sb, Si, Ti, Cr, Mg, Fe, Co, Ni, Zr, Mo, Ag, Cd, Pb, In, Hf, Sn and rare-earth elements as accessory components and in that it is comprised of a balance of Cu and unavoidable impurities.

(2) A high-strength copper alloy with high electrical conductivity and superior oxide film adhesiveness characterized in that it contains from 0.1 weight % to 10 weight % Mn, in that it contains a total quantity of from 0.01 weight % to 10 weight % of one or two or more elements selected from the group comprised of the following: B, P, Be, Al, As, Sb, Si, Ti, Cr, Mg, Fe, Co, Ni, Zr, Mo, Ag, Cd, Pb, In, Hf, Sn and rare-earth elements as accessory components, in that it is comprised of a balance of Cu and unavoidable impurities, in that its surface roughness, that is, the center-line average roughness (Ra), is less than 0.20  $\mu\text{m}$  and in that its maximum height ( $R_{\text{max}}$ ) is less than 1.5  $\mu\text{m}$ .

### 3. Detailed Description of the Invention

#### [Field of Industrial Use]

This invention relates to a high-strength copper alloy with high electrical conductivity and superior oxide film adhesiveness that can be used for lead materials of semiconductor devices such as transistors and integrated circuits, connectors, terminals, relays and switches.

#### [Prior Art]

Conventionally, high-nickel alloys such as Kovar (Fe-29Ni-16Co) and 42 alloy (Fe-42Ni), which have low thermal expansion coefficients and good element and ceramic bonding and sealing capacity, have been used preferentially as lead materials for semiconductor devices. However, in recent years, ICs of high electrical power consumption have been frequent and accompanying them there has been an increase in the degree of integration of semiconductor circuits. Resins are frequently used as sealing materials and improvements have been made in the bonding of elements and lead frames, with the result that copper base alloys of good heat radiation properties have also come into use for the lead frames that are used.

In general, lead materials for semiconductor devices are required to have the following properties.

(1) Since leads are electrical-signal transmitting components and since they are required to have the function of releasing to the exterior any heat that is generated in the packaging process and during circuit use, they should be made of materials that have superior thermal and electrical conducting properties.

(2) Adhesiveness between leads and molds [substrates] is important from the standpoint of semiconductor element protection, for which reason the coefficients of thermal expansion of the lead material and of the substrate material should be similar.

(3) Various heating processes are applied during packaging, for which reason the lead materials should have good heat resistance.

(4) An oxide film is formed between the resin and the material when the various heating processes are applied during packaging, for which reason oxide film adhesiveness should be adequate.

(5) Almost all leads are made by punch processing or bending processing of the lead materials, for which reason they must be of good processability.

(6) The surfaces of leads are plated with noble metals, for which reason there should be good adhesiveness with these noble metals.

(7) The so-called outer lead parts that are exposed on the outer side of the sealing material after packaging are frequently soldered, for which reason they should exhibit good solderability.

(8) From the standpoints of the reliability and service life of the devices, the lead materials should be of good corrosion resistance.

(9) The lead materials should be of low price.

Further, conventionally, inexpensive brass, nickel, which has superior spring properties and corrosion resistance, or phosphor bronze, which has superior spring characteristics, have been used as materials of springs for electrical devices, springs for measuring instruments and for springs that are

used in switches and connectors. However, in connectors and terminals, there are cases in which sealing is effected with resins and oxide film adhesiveness is required.

[Problems the Invention Is Intended to Solve]

Precipitation and hardening-type copper alloys such as oxygen-free copper, copper containing tin, phosphor bronze, Cu-Fe-P alloy and Cu-Ni-P alloy have been used conventionally as copper alloys in response to the various required properties of semiconductor devices as described above.

However, in recent years, the requirements for reliability of semiconductors have become more rigorous and many surface mounting types have been developed in response to miniaturization. For this reason, oxide film adhesiveness that does not involve conventional problems has become an extremely important property.

Specifically, because heat is applied in the process of packaging of lead frames, an oxide film is inevitably produced. When sealing is effected with a resin and when the adhesiveness of the resin with the oxide film and of the oxide film with the parent material are compared, the adhesive strength of the oxide film with the parent material is generally lower. In this case, peeling occurs between the oxide film and the parent material with the result that water enters and the reliability of the IC is markedly decreased. Consequently, oxide film adhesiveness is one of the most important properties for high-strength copper alloys with high electrical conductivity that are used for lead frame materials.

The oxide film adhesiveness of precipitation and hardening type copper alloys such as the aforementioned copper containing tin, phosphor bronze, Cu-Fe-P alloy and Cu-Ni-P alloy is worse than that of oxygen-free copper and cannot satisfy such rigorous requirements for oxide film adhesiveness. Further, with oxygen-free copper, the requirement for high strength accompanied by miniaturization cannot be satisfied. Accordingly, an improvement of the oxide film adhesiveness of high-strength copper alloys with high electrical conductivity as represented by copper containing tin, phosphor bronze, Cu-Fe-P alloy and Cu-Ni-P alloy is awaited.

[Structure of the Invention]

When the inventors conducted research in the light of these points, it was discovered that the addition of Mn is effective in improving the oxide film adhesiveness of high-strength copper alloys with high electrical conductivity, resulting in providing copper alloys having excellent properties as electrically conductive spring materials such as lead materials, connectors, terminals, relays and switches of semiconductor devices.

Specifically, this invention relates to a high-strength copper alloy with high electrical conductivity and superior oxide film adhesiveness characterized in that it contains from 0.1 weight % to 10 weight % Mn, in that it contains a total quantity of from 0.01 weight % to 10 weight % of one or two or more elements selected from the group comprised of the following: B, P, Be, Al, As, Sb, Si, Ti, Cr, Mg, Fe, Co, Ni, Zr, Mo, Ag, Cd, Pb, In, Hf, Sn and rare-earth elements and in that it is comprised of a balance of Cu and unavoidable impurities and to a high-

strength copper alloy with high electrical conductivity and superior oxide film adhesiveness as described above, characterized in that its surface roughness, that is, the center line average roughness ( $R_a$ ), is less than  $0.20\text{ }\mu\text{m}$  and in that its maximum height ( $R_{\text{max}}$ ) is less than  $1.5\text{ }\mu\text{m}$ .

[Specific Description of the Invention]

We shall now explain the reasons for the limitations on the alloy components that constitute the alloy of this invention.

As a result of the fact that Mn is added to the copper alloy, the oxide film adhesiveness of the copper alloy is improved and its strength is also increased. The reason why its content is set to greater than 0.1 weight % and less than 10 weight % is that there is no effect when the content is less than 0.1 weight % and that there is marked deterioration of processability and conductance when it exceeds 10 weight %.

The reason why it contains one or two or more elements selected from the group comprised of the following: B, P, Be, Al, As, Sb, Si, Ti, Cr, Mg, Fe, Co, Ni, Zr, Mo, Ag, Cd, Pb, In, Hf, Sn and rare-earth elements is that its strength can be increased without bringing about a marked decrease in conductance by adding these elements individually or in combinations. When the content is less than 0.01 weight %, there is little increase in strength. When it exceeds 10 weight %, there is a marked decrease in conductance and there is deterioration in processability and solderability.

The reason why surface roughness is set to less than  $0.20\text{ }\mu\text{m}$  for the center-line average roughness ( $R_a$ ) and that the maximum roughness ( $R_{\text{max}}$ ) is

set to less than 1.5  $\mu\text{m}$  is that the oxide film adhesiveness is improved by making the surface smooth.

[Examples]

We shall now describe this invention in more specific terms by presenting examples.

Ingots (30 mm  $\times$  60 mm  $\times$  120 mm) of alloys of various component compositions as shown in Table 1 were prepared as alloys of this invention and as comparison alloys. Next, the surface of the ingot was planed, after which it was hot rolled at 850°C to a thickness of 8 mm. The surface was planed, after which it was cold-rolled to 1.5 mm. Following that, melting treatment was performed for 10 minutes at 850°C. It was then cooled at a rate of greater than 10°C/second and washed with acid, and it was cold-rolled to a thickness of 0.25 mm. These test materials were subjected to aging treatment for a specified time at 400°C in a vacuum annealing furnace so that their surfaces did not undergo oxidation. The surface roughness of the test materials was adjusted by changing the type of roller used in the final cold rolling.

The items used for evaluation of lead frames and springs were as follows. Strength and elongation were determined on the basis of tensile strength. Bendability was determined by repeated bending of 90°, and the frequency of back-and-forth bending up to the breaking point was determined. Electrical conductivity (heat radiation) was shown by conductance (% IACS). Solderability was evaluated by the perpendicular immersion method in which the sample was immersed for 5 seconds in a solder bath (60% tin, 40% lead) at  $230 \pm 5^\circ$ , with the



state of moisture of the solder being observed macroscopically. Plating adhesiveness was evaluated by plating with Ag to a thickness of 3  $\mu$ , the test material was heated for 5 minutes at 450°C and it was determined by macroscopic visual observation whether or not there was any blistering on the surface.

Evaluation of spring characteristics was performed by determining the spring threshold value.

Oxide film adhesiveness was evaluated by heating the test material in the atmosphere for 3 minutes at a temperature of 200 to 500°C to produce an oxide film on the surface, adhesive tape then being affixed to the surface of the test material and it being determined whether or not there was peeling of the oxide film when the tape was stripped off rapidly. The temperatures at which peeling of the oxide films occurred are shown.

Table 1 is explained below.

As should be evident from Table 1, it was found that the alloys of this invention exhibited oxide film adhesiveness that was markedly superior to that of the comparison alloys.

Although alloy Nos. 6, 7 and 9 of this invention have the same respective accessory components as the Comparison Alloy Nos. 16, 17 and 20, the Comparison Alloy Nos. 16, 17 and 20 do not contain Mn, for which reason their oxide film adhesiveness was poor. Further, although Comparison Alloy No. 18 was tough pitch copper, its strength as a spring material was insufficient. In

addition, because Comparison Alloy No. 19 did not contain Mn and did not contain accessory components, its strength as a spring material was insufficient.

[Effect of the Invention]

The alloys of this invention have sufficient mechanical strength, conductance, repeated bending capacity, solderability, plating adhesiveness and oxide film adhesiveness and are suitable as high-strength copper alloys with high electrical conductivity and superior oxide film adhesiveness that can be used for lead materials of semiconductor devices such as transistors and integrated circuits, connectors, terminals, relays and switches.

Table 1

Group	Alloy No.	Chemical components (weight %)			Surface roughness ( $\mu\text{m}$ )	Tensile strength [ $\text{kg}/\text{mm}^2$ ]	Elongation (%)	Conductance (% IACS)	Repeat-ability	Solder-ability	Plating adhesion (presence or absence of blisters)	Oxide film adhesion (temperature at which peeling begins)	Spring threshold value ( $\text{kg}/\text{mm}^2$ )
		Cu	Zn	Other									
Alloys of this invention	1	Balance	1.0	2.0 Ni	0.06	0.5	48	34	4 5	Excellent	None	350	33
	2	Balance	1.5	1.0 Sn	0.08	1.0	49	42	5 4	Excellent	None	400	34
	3	Balance	1.6	0.3 Si	0.08	0.9	41	38	5 5	Excellent	None	375	29
	4	Balance	0.8	1.6 Ni, 0.4 Si	0.05	0.5	62	40	4 5	Excellent	None	350	43
	5	Balance	0.3	0.5 Cr, 0.2 Zr, 0.02 B	0.06	0.5	61	67	5 5	Excellent	None	400	42
	6	Balance	0.8	2.5 Fe, 0.03 P	0.05	0.6	43	51	5 4	Excellent	None	375	30
	7	Balance	1.5	2.0 Ni, 0.5 Si, 0.06 Mg	0.08	1.0	70	30	4 3	Excellent	None	350	49
	8	Balance	1.6	1.25 Ni, 0.18 P, 0.01 Pb	0.06	0.8	63	38	4 4	Excellent	None	375	37
Comparative alloys	9	Balance	1.6	2.0 Sn, 0.10 Mo, 0.03 P	0.05	0.7	54	20	5 4	Excellent	None	350	37
	10	Balance	2.0	0.8 Ni, 0.5 Co, 0.03 In	0.06	0.9	53	35	5 5	Excellent	None	400	38
	11	Balance	2.0	0.2 Ag, 0.2 Cd	0.10	1.2	42	52	5 4	Excellent	None	400	30
	12	Balance	0.6	0.1 Fe, 0.02 P, 0.2 Be	0.07	0.9	55	60	4 5	Excellent	None	375	39
	13	Balance	1.0	6.2 Sn, 0.10 P	0.04	0.5	62	10	5 4	Excellent	None	325	44
	14	Balance	1.2	0.25 Ti, 0.6 Al	0.05	0.6	54	48	4 4	Excellent	None	375	38
	15	Balance	5.0	0.08 Hf, 0.05 As	0.05	0.5	41	16	4 5	Excellent	None	425	28
	16	Balance	--	2.5 Fe, 0.03 P	0.05	0.6	42	64	5 4	Excellent	None	325	29
	17	Balance	--	2.0 Ni, 0.5 Si, 0.06 Mg	0.08	1.0	70	42	4 4	Excellent	None	300	50
	18	Balance	--	--	0.06	0.7	33	100	6 5	Excellent	None	400	22

19	Balance	1.5	—	0.05	0.6	35	12	48	5	5	Excellent	None	400	25
20	Balance	—	2.0 Sn, 0.10 Mo, 0.03 P	0.05	0.7	52	11	30	5	4	Excellent	None	275	38

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⑭ 発明の名称 酸化膜密着性に優れた高力高導電性銅合金

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## 1. 発明の名称

酸化膜密着性に優れた高力高導電性銅合金

## 2. 特許請求の範囲

(1) Mn 0.1重量%以上10重量%以下を含み、さらに副成分としてB、P、Be、Al、As、Sb、Si、Ti、Cr、Mg、Fe、Co、Ni、Zr、Mo、Ag、Cd、Pb、In、Hf、Sn、希土類元素からなる群より選択された1種又は2種以上を総量で0.01重量%以上10重量%以下を含み、残部Cuおよび不可避免的不純物からなることを特徴とする酸化膜密着性に優れた高力高導電性銅合金。

(2) Mn 0.1重量%以上10重量%以下を含み、さらに副成分としてB、P、Be、Al、As、Sb、Si、Ti、Cr、Mg、Fe、Co、Ni、Zr、Mo、Ag、Cd、Pb、In、Hf、Sn、希土類元素からなる群より選択された1種又は2種以上を 量で0.01重量%以上10重量%以下を含み、残部Cuおよび不可避免的不純物からなり、表面粗さが中心線平均粗さ(Ra)で0.20μm

以下、最大高さ(Rmax)で1.5μm以下であることを特徴とする酸化膜密着性に優れた高力高導電性銅合金。

## 3. 発明の詳細な説明

〔産業上の利用分野〕

本発明はトランジスタや集積回路などの半導体機器のリード材やコネクタ、端子、リレー、スイッチなどの導電性ばね材に適する銅合金に関し、特に酸化膜密着性に優れた高力高導電銅合金に関するものである。

〔従来の技術〕

従来、半導体機器のリード材としては、熱膨張係数が低く、素子及びセラミックとの接着及び封止性の良好なコパール(Fe-29Ni-16Co)、42合金(Fe-42Ni)などの高ニッケル合金が好んで使われてきた。しかし、近年、半導体回路の集積度の向上に伴い消費電力の高いICが多くなってきたことと、封止材料として樹脂が多く使用され、かつ素子とリードフレームの接着も改良が加えられたことにより、使用されるリード材も放熱性の

よい銅基合金が使われるようになってきた。

一般に半導体機器のリード材としては以下のよう  
な特性が要求されている。

- (1) リードが電気信号伝達部であるとともに、パッケージング工程中及び回路使用中に発生する熱を外部に放出する機能を併せ持つことを要求される為、優れた熱及び電気伝導性を示すもの。
- (2) リードとモールドとの密着性が半導体素子保護の観点から重要であるため、リード材とモールド材の熱膨張係数が近いこと。
- (3) パッケージング時に種々の加熱工程が加わる為、耐熱性が良好であること。
- (4) パッケージング時に種々の加熱工程が加わる際、樹脂と素材の間に酸化膜が生ずる為、酸化膜密着性が良好なこと。
- (5) リードはリード材を抜き打ち加工し、又曲げ加工して作製されるものがほとんどである為、これらの加工性が良好なこと。
- (6) リードは表面に貴金属のメッキを行う為、これら貴金属とのメッキ密着性が良好であること。

ブが多くなってきたため、従来問題とされていなかった酸化膜密着性が非常に重要な特性項目となってきた。

すなわち、リードフレームはパッケージングの過程で熱が加わるため、酸化膜が必ず生成される。樹脂等で封止された場合、樹脂と酸化膜、酸化膜と母材との密着強度を比べると、酸化膜と母材との密着強度が一般に低い。この場合、酸化膜と母材との間に剥離が生じることがあり、そこから水分等が入り、ICの信頼性を著しく低下させてしまう。従って、酸化膜密着性はリードフレーム材等に用いられる高力高導電銅合金として最も重要な特性の一つである。

前述の銅入り銅、りん青銅およびCu-Fe-P合金やCu-Ni-Si合金などの析出硬化型銅合金の酸化膜密着性は無酸素銅より悪く酸化膜密着性の厳しい要求を満足することができなくなってきた。また、無酸素銅では小型化に伴う高い強度の要求を満足することができなくなってきた。そこで、銅入り銅、りん青銅およびCu-Fe-P合金やCu-

- (7) パッケージング後に封止材の外に露出している、いわゆるアウター・リード部に半田付けするものが多いので良好な半田付け性を示すこと。
- (8) 機器の信頼性及び寿命の観点から耐食性が良好なこと。
- (9) 価格が低廉であること。

又、従来電気機器用ばね、計測器用ばね、スイッチ、コネクター等に用いられるばね用材料としては安価な黄銅、優れたばね特性及び耐食性を有する洋白あるいは優れたばね特性を有するりん青銅が使用されているがコネクター、端子等でも樹脂封止されるものも有り酸化膜密着性が要求される。

〔発明が解決しようとする問題点〕

上述の半導体機器に対する各種の要求特性に対し、従来銅合金としては無酸素銅、銅入り銅、りん青銅およびCu-Fe-P合金やCu-Ni-P合金などの析出硬化型銅合金が使用されていた。

しかし、近年半導体に対する信頼性がより厳しくなるとともに、小型化に対応した面付実装タイ

Ni-Si合金などに代表される高力高導電銅合金の酸化膜密着性を改善することが待ち望まれていた。

〔発明の構成〕

本発明者らは上記の点に鑑み研究を行ったところ、高力高導電銅合金の酸化膜密着性の改善にMnの添加が有効であることを見出し、半導体機器のリード材やコネクター、端子、リレー、スイッチなどの導電性ばね材として好適な諸特性を有する銅合金を提供するに至った。

すなわち本発明は、Mn 0.1重量%以上10重量%以下を含み、さらに副成分としてB、P、Be、Al、As、Sb、Si、Ti、Cr、Mg、Fe、Co、Ni、Zr、Mo、Ag、Cd、Pb、In、Hf、Sn、希土類元素からなる群より選択された1種又は2種以上を総量で0.01重量%以上10重量%以下を含み、残部Cuおよび不可避免的不純物からなることを特徴とする酸化膜密着性に優れた高力高導電性銅合金並びに表面粗さが中心線平均粗さ(Ra)で0.20μm以下、最大高さ(Rmax)で1.5μm以下であることを特徴とする前記記載の酸化膜密着性に優れた高力高導電性銅合金

に関する。

〔発明の具体的説明〕

次に本発明合金を構成する合金成分の限定理由を説明する。

Mnは銅合金に添加することにより、銅合金の酸化膜密着性を改善し、また、強度を向上させるが、含有量を0.1重量%以上10重量%以下とする理由は、0.1重量%未満ではその効果がなく、10重量%を超えると、加工性、導電率の劣化が著しいためである。

また副成分のB、P、Be、Al、As、Sb、Si、Ti、Cr、Mg、Fe、Co、Ni、Zr、Mo、Ag、Cd、Pb、In、Hf、Sn、希土類元素からなる群より選択された1種又は2種以上を総量で0.01重量%以上10重量%以下含有する理由は、これらの元素は単独または複合で添加されることにより導電率を著しく低下させずに強度を向上することができるからで、0.01重量%未満では強度の向上が少なく、10重量%を超えると導電率の低下が著しく、また、加工性、半田付け性が劣化するためである。

曲げ回数を測定し、電気伝導性（放熱性）を導電率（%IACS）によって示した。半田付け性は、垂直式浸漬法で $230 \pm 5^\circ\text{C}$ の半田浴（錫60%、鉛40%）に5秒間浸漬し、半田のぬれの状態を目視観察することにより評価した。メッキ密着性は試料に厚さ3 $\mu$ mのAgメッキを施し、 $450^\circ\text{C}$ にて5分間加熱し、表面に発生するフクレの有無を目視観察することにより評価した。

ばね性の評価は、ばね限界値を測定することにより行った。酸化膜密着性については、素材を $200^\circ\text{C} \sim 500^\circ\text{C}$ で3分間大気中で加熱して表面に酸化膜を生成させ、その酸化膜に粘着テープをはった後、一気にはがして酸化膜の剥離の有無により評価を行った。剥離が生じた酸化膜の生成温度を求めた。

第1表について以下説明する。

第1表から明らかなように本発明合金は比較合金と比べて酸化膜密着性が著しく優れていることがわかる。

本発明合金No6、7、9と比較合金No16、17、20

また、表面粗さを中心線平均粗さ（Ra）で $0.20 \mu\text{m}$ 以下、最大高さ（Rmax）で $1.5 \mu\text{m}$ 以下とするのは、表面を平滑にすることにより酸化膜密着性を向上させるためである。

〔実施例〕

次に本発明を具体的に説明する。

第1表に示す本発明合金及び比較合金に係る各種成分組成のインゴット（ $30\text{mm} \times 60\text{mm} \times 120\text{mm}$ ）を溶製し、インゴット面削を行った後、 $850^\circ\text{C}$ で熱間圧延を行い、8mmの厚さとし、面削後1.5mmまで冷間圧延した。その後 $850^\circ\text{C}$ で10分間溶体化処理を行い、 $10^\circ\text{C}/\text{sec}$ 以上の速度で冷却し、酸洗後、厚さ0.25mmまで冷間圧延を行った。これらの供試材を真空焼鈍炉にて表面が酸化されない様に $400^\circ\text{C}$ にて所定時間時効処理を行った。なお、供試材の表面粗さは、最終冷間圧延のロールの種類を換えることにより調整した。

リード材及びばね材としての評価項目として強度、伸びを引張試験により、曲げ性を $90^\circ$ 繰り返し曲げ試験により一往復を1回として破断までの

は各々の副成分は同じだが、比較合金No16、17、20はMnが含まれていないため酸化膜密着性が悪い。また、比較合金No18はタフピッチ銅であるが、ばね材としては強度が不足している。また比較合金No19はMnのみ含有し、副成分は含まれていないため、ばね材として強度が不足している。

〔発明の効果〕

本発明合金は十分な機械的強度、導電率、くり返し曲げ性、半田付け性、めっき密着性および酸化膜密着性を有し、半導体機器のリード材やコネクタ、端子、リレー、スイッチなどに用いる高力高導電性銅合金として好適である。

以下余白



区分	No.	化 学 成 分 (重量%)			表面粗さ ( $\mu\text{m}$ )		引張強さ ( $\text{kg}/\text{mm}^2$ )	伸び (%)	導電率 (% IACS)	くり返し 曲 げ 性 上	半だ付け性	めっき密着性 (79リチウム型)	酸化腐蝕性 (異種金属露出)	ばね限界値 ( $\text{kg}/\text{mm}^2$ )
		Cu	Rn	そ の 他	Ra	Rmax								
本 発 明 の 合 成 金	1	残	1.0	2.0Ni	0.06	0.5	48	10	34	4 5	良 好	無	350	33
	2	"	1.5	1.0Sn	0.08	1.0	49	12	42	5 4	良 好	無	400	34
	3	"	1.6	0.3Si	0.08	0.9	41	9	38	5 5	良 好	無	375	29
	4	"	0.8	1.6Ni, 0.4Si	0.05	0.5	62	11	40	4 5	良 好	無	350	43
	5	"	0.3	0.5Cr, 0.2Zr, 0.02B	0.06	0.5	61	9	67	5 5	良 好	無	400	42
	6	"	0.8	2.5Fe, 0.03P	0.05	0.6	43	8	51	5 4	良 好	無	375	30
	7	"	1.5	2.0Ni, 0.5Si, 0.06Mg	0.08	1.0	70	12	30	4 3	良 好	無	350	49
	8	"	1.6	1.25Ni, 0.18P, 0.01Pb	0.06	0.8	63	9	38	4 4	良 好	無	375	37
	9	"	1.6	2.0Sn, 0.10Mo, 0.03P	0.05	0.7	54	10	20	5 4	良 好	無	350	37
	10	"	2.0	0.8Ni, 0.5Co, 0.03In	0.06	0.9	53	12	35	5 5	良 好	無	400	38
	11	"	2.0	0.2Ag, 0.2Cd	0.10	1.2	42	10	52	5 4	良 好	無	400	30
	12	"	0.6	0.1Fe, 0.02P, 0.28e	0.07	0.9	55	14	60	4 5	良 好	無	375	39
	13	"	1.0	6.25Ni, 0.10P	0.04	0.5	62	12	10	5 4	良 好	無	325	44
	14	"	1.2	0.25Ti, 0.5Al	0.05	0.6	54	9	48	4 4	良 好	無	375	38
	15	"	5.0	0.08Hf, 0.05As	0.05	0.5	41	10	16	4 5	良 好	無	425	28
比 較 合 金	16	"	—	2.5Fe, 0.03P	0.05	0.6	42	9	64	5 4	良 好	無	325	29
	17	"	—	2.0Ni, 0.5Si, 0.06Mg	0.08	1.0	70	12	42	4 4	良 好	無	300	50
	18	"	—	—	0.06	0.7	33	10	100	6 5	良 好	無	400	22
	19	"	1.5	—	0.05	0.6	35	12	48	5 5	良 好	無	400	25
	20	"	—	2.0Sn, 0.10Mo, 0.03P	0.05	0.7	52	11	30	5 4	良 好	無	275	38

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